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Rationale and Definition of The Criteria of The Efficiency of The Biological Activity of Optical Radiation on Animal Organism.

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Abstract

In today's technological development of human society more and more influence on the lives of biological organisms different electromagnetic radiation. Therefore, the study and analysis of the mechanisms of their effects is an urgent task. The purpose of research - the study of the primary mechanisms of interaction of photons of optical radiation with the structures of biological objects, using the laws of quantum mechanics and biophysics. Photobiological basis of the mechanism of action of EMR optical range is the energy absorption of light quanta (photons) by atoms and molecules of biological structures (law Grotgus-Draper), which resulted in the formation of electronically excited states of these molecules with the transfer of photon energy (internal photoeffect). This is accompanied by electrolytic dissociation and ionization of biological molecules. The degree of manifestation of photobiological effects in the body depends on the intensity of the optical radiation, which is inversely proportional to the square of the distance from the source to the irradiated surface. Accordingly, in practice, determine not the intensity and irradiation dose at a certain distance from the source of exposure by the exposure time.

Keywords: Efficiency, Biological Activity, Optical Radiation, Animal Organism.

1. The results of research

Interaction of electromagnetic radiation (EMR) from the optical range of biologic objects as shown in the wave, and quantum effects in the probability of formation of which varies depending on the wavelength. In assessing the effectiveness of EMR in the optical range, along with such laws of its wave propagation, as a reflection, scattering and absorption, it is also necessary to take into account the effects of corpuscular - photochemical, photoelectric, photolytic and others. Photobiological basis of the mechanism of action of EMR optical range is the energy absorption of light quanta (photons) by atoms and molecules of biological structures (law Grotgus-Draper), which resulted in the formation of electronically excited states of these molecules with the transfer of photon energy (internal photoeffect). This is accompanied by electrolytic dissociation and ionization of biological molecules.

The degree of manifestation of photobiological effects in the body depends on the intensity of the optical radiation, which is inversely proportional to the square of the distance from the source to the irradiated surface. Accordingly, in practice, determine not the intensity and irradiation dose at a certain distance from the source of exposure by the exposure time.

At the irradiation of biological objects and the study of various photobiological reactions to determine the criterion of the effectiveness of optical radiation, use the concept of dose, or exposure to optical radiation.

The dose of irradiation determines the amount of energy of optical radiation absorbed in the volume of the irradiated biological object and causes the formation of certain products.

In most photobiological studies, the only determining criterion is the dose (exposure) of radiant energy falling on the surface of the irradiated body:

$$\eta = \frac{M}{N_f} \qquad (2)$$

Where

η - is the quantum yield of photoreaction;

M- number of reacted molecules;

N_f - is the number of photons of optical radiation penetrating into the body's thickness of the irradiated object and interacting with its molecules.

From (2) determine the number of absorbed photons

$$N_f = \frac{M}{\eta} \qquad (3)$$

Accordingly, the number of molecules (M) reacted according to the laws of physical chemistry can be defined as:

$$M = \frac{g \cdot N_A}{G} \qquad (4)$$

Where

N_A - the Avogadro number, 6.03 * 1023, which characterizes the number of molecules in gram-mol of this substance, the mass G,

g - the mass of the reactant substance.

Since any photoreaction has its duration, the number of absorbed photons N_f for time t (absorbed energy)is defined as:

$$N_f = n \times t \qquad (5)$$

here n - number of absorbed photons of radiation for the period t.

Substituting the values (4) and (5) in (3) we obtain an expression

$$n \cdot t = \frac{g \cdot N_A}{G \cdot \eta} \qquad (6)$$

multiplying the left and right part of expression (6) by the energy of the quantum of optical radiation (ε), we obtain the Vant-Hoff-Lazarev equation for the photochemical reaction, on the left side of which is an expression defining the amount of energy of optical radiation absorbed by the irradiated body; and on the right side is an expression that defines the energy consumed in the process of photo reaction:

$$n \cdot t \cdot \varepsilon = \frac{g \cdot N_A}{G \cdot \eta} \varepsilon \qquad (7)$$

Since the energy of a quantum depends on the wavelength of the optical radiation λ (that is, the spectrum of optical radiation), expression (7) should be presented in this way:

$$n \cdot t \cdot \varepsilon_{\lambda} = \frac{g \cdot N_A}{G \cdot \eta} \varepsilon_{\lambda} \quad (8)$$

where - index λ notes that absorbed monochromatic radiation with a wavelength equal to λ nm.

The analysis of formula (8) shows that the left-hand side determines the amount of absorbed optical energy W during irradiation t.

$$W = n \cdot t \cdot \varepsilon_{\lambda} = N_{\phi} \cdot \varepsilon_{\lambda} \quad (9)$$

Using the law of Bouguer-Lambert-Ber, we define the energy absorbed by the object through the energy falling from its source on the surface of the optical radiation incident on its surface:

$$W = W_p \cdot (1 - e^{-kl}) \quad (10)$$

where *l* - the thickness of the irradiating layer of matter; k - indicator of absorption of radiation by molecules in the object of irradiation in the thickness of the irradiation layer.

We express the energy falling on the substance through the flow of radiation F_p falling on its surface

$$W_p = F_p \cdot t \quad (11)$$

The energies absorbed by the structures effectively (10) will be determined as

$$W = F_p \cdot t(1 - e^{-kl}) \quad (12)$$

Divide the left and right sides of expression (12) into the area of the irradiated surface S and, thus, determine the energy falling from the radiation source per unit area of the surface of the irradiated object

$$\frac{W}{S} = \frac{F_p}{S} t(1 - e^{-kl}) \quad (13)$$

Replacing the relation $\frac{F_p}{S}$ through E - irradiation of the surface of the object is obtained:

$$\frac{W}{S} = E \cdot t(1 - e^{-kl}) \quad (14)$$

The multiplication Et (according to expression (1) determines the amount of energy falling on the surface of the irradiated object during time t, or the dose of irradiation D.

Consequently, from expression (14), the dose of irradiation will be determined as

$$D = \frac{W}{S(1 - e^{-kl})} \qquad (15)$$

By replacing $(1\text{-}e^{-kl})$ through α - the absorption coefficient of radiation and presenting the absorbed energy W through the right part of expression (8), we obtain an expression for determining the dose of radiation of the biological object D of the biological object with the wavelength λ nm required to excite the photoreaction of the molecules by a general weight g

$$D_\lambda = \frac{g \cdot N_A \cdot \varepsilon_\lambda}{G \cdot \eta_\lambda \cdot S \cdot \alpha_\lambda} \qquad (16)$$

Let us denote the relation $\frac{\varepsilon_\lambda}{\eta_\lambda}$ by μ_λ-energy photoconductivity coefficient of the radiation photon with wavelength λ, then the dose of irradiation through the number of reacted molecules (in the range of the radiation spectrum from λ_1, to λ_2) can be defined as

$$D_{(\lambda_1 - \lambda_2)} = \int_{\lambda_1}^{\lambda_2} \frac{g \cdot N_A}{G \cdot S \cdot \alpha(\lambda)} \mu(\lambda) d\lambda \qquad (17)$$

or through a photo-reaction product

$$D_{(\lambda_1 - \lambda_2)} = \frac{g \cdot N_A}{G \cdot S} \int_{\lambda_1}^{\lambda_2} \frac{\mu(\lambda)}{\alpha(\lambda)} d\lambda \text{ or } D_{(\lambda_1 - \lambda_2)} = \frac{M}{S} \int_{\lambda_1}^{\lambda_2} \frac{\mu(\lambda)}{\alpha(\lambda)} d\lambda \qquad (18)$$

Where

g NA / G = M - the number of photo reaction product produced by the action of radiation (in the range of the radiation spectrum from λ_1, to λ_2);

μ (λ) - is the spectral energy coefficient of the photo of radiation reactivity with the wavelength λ;

α (λ)- spectral absorption coefficient of radiation with wavelength λ in the thickness of the irradiated object;

S - the value of the area of the irradiated surface of the object.

Analyzing the expressions (19) from the standpoint of the task, namely: determining the amount of energy of optical radiation W needed to obtain the quantity of product of a given photo reaction, it can be stated that according to this dependence, the real dose of radiation necessary for the formation in this biological object is determined, Specific amount of photo reaction product.

This approach differs from the generally accepted method of dosage, in which only the dose of incident energy is determined on the object of radiation, the value of which is always more than energy efficiently absorbed. On the basis of the above shown, one can write the correct mathematical model of the interaction of the energy of optical radiation with the structures of the animal organism in the form:

$$\frac{M}{S} \int_{\lambda_1}^{\lambda_i} \frac{\mu(\lambda)}{\alpha(\lambda)} d\lambda = \frac{t}{S} \int_{\lambda_1}^{\lambda_i} F_p(\lambda) d\lambda \qquad (19)$$

where

- the left side of the expression determines the amount of optical radiation energy with a wavelength from λ_1 to λ_i and is effectively used to form a given (M) amount of photo reaction product in the body of the irradiated animal body,
- the right side of the expression shows the energy of the radiation flux (F_p) from the source of optical radiation of the same range that falls on the surface of the biological object (S) and in time (t) causes the formation of a specified quantity of product (M) reaction (for example, organic matter with photosynthesis, or vitamin D in the body of an animal..).

As a result, we can say that expression (19) shows the energy connection of an optical radiation source with an object of radiation and provides an opportunity to solve important practical problems:

- For the given species of animals or plants on the basis of known optical characteristics of their coverage and determined spectra of the biological effect of optical radiation energy, a practical opportunity to find the most effective source of optical radiation to ensure the optimal passage of this photo reaction in the organism of an irradiated animal or plant.
- Possibility to predict and set quantitative and qualitative results of the irradiation process in a given spectrum of biological action;
- Possibility to provide precise energy-efficient automatic control and control of the technological process of irradiation and regulation of the dose of radiation.

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